Translocation as a conservation tool: case studies from rare freshwater fishes in Scotland

Colin E. Adams[1], Alex A. Lyle[2], Jennifer A. Dodd[1], Colin W. Bean[3], Ian J. Winfield[4], Andy R.D.Gowans[5], Alastair Stephen[6] and Peter S. Maitland[7]

[1]Scottish Centre for Ecology and the Natural Environment, University of Glasgow, Rowardennan, Glasgow G63 0AW, Scotland.
[2]ALP, 18 John Knox Road, Longniddry EH32 0LP, U.K.
[3]Scottish Natural Heritage, Caspian House, Mariner Court, Clydebank Business Park, Clydebank G81 2NR
[4]Lake Ecosystems Group, Centre for Ecology & Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster LA1 4AP, U.K.
[5]Environment Agency, Ghyll Mount, Gillan Way, Penrith 40 Business Park, Penrith CA11 9BP
[6]Scottish & Southern Energy, Inveralmond House, 200 Dunkeld Road, Perth PH1 3AQ
[7]Fish Conservation Centre, Gladshot, Haddington EH41 4NR

E-mail: colin.adams@glasgow.ac.uk

ABSTRACT
The use of translocation of animals to an ecosystem to which they are not native as a conservation strategy is controversial, but may be the only choice where *in situ* intervention is not possible. This strategy has been used to establish conservation refuge site populations for three important species of rare freshwater fishes in Scotland. Eleven translocations have been initiated over the last four decades in Scotland, five of these have resulted in the successful establishment of conservation refuges populations of Arctic charr, powan and vendace. The outcome of the remaining six is not yet certain. The approach taken has enabled the protection of, not only important species, but also of the considerable and discrete between-population diversity in phenotype and genotype that is found in these species.

INTRODUCTION

Although somewhat controversial (Müller & Eriksson, 2013), the use of translocation of plants and animals as a conservation strategy is increasing (Linklater et al., 2011). Translocation is normally considered appropriate in situations where a natural population is under threat and where *in situ* management intervention is not technically or economically possible. At its simplest, when used as a conservation tool, translocation usually involves the movement of individuals taken from a natural population to one or more suitable sites outside its current range to form a "conservation refuge" or "Ark" site (Maitland & Lyle, 2013). A flourishing scientific literature describing theoretical, practical and ethical studies of this technique, its appropriateness, success rate and, the consequences of its use has been recently stimulated by consideration of potential conservation responses to climate change (Albrecht et al., 2012; Coleman et al., 2013; Chauvenet et al., 2013; Thrimawithana et al., 2013; Zeisset & Beebee, 2013). Of particular concern in this context, is the potential of plants and animals with poor powers of dispersal to adjust their range to track changes in the environment driven by climate change (Chauvenet et al., 2013).

Obligate freshwater fishes have poor powers of dispersal in the sense that they have very limited ability to move between (and sometimes within) unconnected water catchments (Adams & Maitland, 2001). Populations of obligate freshwater fishes of high conservation value have thus very little opportunity to disperse and avoid the negative effects of local environmental change in the habitats that they occupy naturally. This makes freshwater fishes particularly strong candidates for translocation intervention when conservation action is required.

In Scotland, a number of conservation translocations have been made to provide protection for freshwater fish species of high conservation value (Maitland & Lyle 1990). Arctic charr (*Salvelinus alpinus* (L.)), Powan (*Coregonus lavaretus* (L.)), vendace (*Coregonus albula* (L.)) and sparling (Smelt) (*Osmerus eperlanus* (L.)) have all been subject to this form of conservation action (see Maitland et al., 2009 on Sparling tranlocation). Here we review these actions for three of these species (Arctic charr, powan and vendace).

The Arctic charr in Scotland is a relatively common lake dwelling fish (Maitland, 2007) but there is significant between-population structuring in both phenotype (Adams et al., 2007) and genetics (Wilson et al., 2004) across the species. This has resulted from rapid evolutionary divergence of populations occupying different lochs in different catchments and more surprisingly between lochs within the same catchment (Alexander & Adams, 2000; Adams et al., 2007) . The resulting effect is that different populations differ significantly in morphology, ecology, life-history characteristics and genetics. For this reason it is reasonable to argue that each population represents a significantly different biological entity that may require protection.

The distribution of the powan is considerably more restricted, occurring naturally in only two Scottish lochs, Lochs Lomond and Eck. There are no plausible records of this species having occurred naturally elsewhere in Scotland in the historical literature covering the last two centuries; although prior to this, there is no good reason to suggest that its distribution was not more widespread. As with Arctic charr, there is significant evidence to show that powan from these two natural populations differ significantly in morphology, parasite fauna, feeding ecology and life-history (Etheridge et al., 2012, and references therein). Restricted to only two sites at which the populations differ significantly, powan are highly vulnerable to any environmental change at either site. In 1982, a considerable threat to powan in Loch Lomond was identified. A non-native fish species, the ruffe (*Gymnocephalus cernuus* (L.)) was discovered there (Maitland et al., 1983); the population expanded rapidly to a reach a very large population size over the following years (Adams & Maitland, 1998). This fish is known to prey upon fish eggs and was shown to be preying heavily upon the eggs of powan (Adams & Tippett, 1991).

The vendace, a close relative of the powan, had a restricted natural distribution in Scotland being restricted to only two glacial kettle lochs located near the town of Lochmaben in Dumfriesshire. The Mill Loch is small in area (13 ha) but relatively deep (16.8 m max) whereas the larger Castle Loch (78.2 ha) is shallow (5.5 m max) and thus these lochs could have supported only relatively small populations. Vendace were sampled from Mill Loch in 1966 by one of the authors (PSM) by which time the Castle Loch population was almost certainly extinct (Maitland, 1966). Further sampling showed that the Mill Loch population also became extinct sometime between 1966 and the mid-1970s (Maitland & Lyle, 2013) At this time the only other populations of vendace in the UK were in Bassenthwaite Lake and Derwent Water, two interconnected lakes in the English Lake District (Maitland, 1966).

CONSERVATION TRANSLOCATIONS OF ARCTIC CHARR, POWAN AND VENDACE

There have been at least 11 concerted conservation translocations, (which have been undertaken under licence) of these three species in the last 40 years. Six of these are described in detail elsewhere and thus only a brief summary is presented here, more detail is provided on the remaining translocations.

Arctic charr

Megget and Talla Reservoirs

Loch Doon supports a population of Arctic charr which, by the 1980s, was at risk from acidification (Maitland et al. 1990). Between 1986 and 1990 a programme of translocation of adult fish and juveniles to Talla Reservoir and of unfed fry (hatched from eggs collected from 101 females) to the nearby Megget Reservoir both in the Scottish Borders (Table 1, Fig. 1) was conducted. In Talla, the charr are known to have spawned successfully within two years and in Megget, charr were recorded in gillnet sampling in 2010 (see Maitland & Lyle 2013 for more detail).

Vendace

Daer resevoir

Vendace sourced from Derwent Water were translocated to Daer Reservoir (Figure 2) in 1998 and again in 2005 and 2008 (Table 1; for more detail see Maitland & Lyle, 2013). The 1998 transfer was of 12,800 unfed fry and, in 2005 & 2008 an additional 25 adult individuals and 32,300 eggs were also translocated. Survey netting in 2003 and again in 2009 found no evidence of establishment success however it is likely that fish from the 2005 and 2008 translocations would not have been easily detected in the 2009 survey. Thus the success of this translocation remains uncertain (see Maitland and Lyle 2013).

Loch Skeen

Vendace sourced from Bassenthwaite Lake in the English Lake District were translocated as 17,500 unfed fry and 47,500 eyed eggs to Loch Skeen in the upper catchment of the River Annan in 1997 and 1999 (Table 1; Fig. 2). Subsequent survey work showed the establishment of a large population of vendace there (see more detail in Maitland & Lyle (2013) and references therein). Ironically the source population for this translocation, Bassenthwaite Lake, is now thought to have become extinct (Winfield et al., 2012) thus Loch Skeen may provide the only available extant conservation material for any future conservation measures for this population.

Loch Valley

Loch Valley lies in the Galloway Forest Park and was the site chosen for an early trial of Mill Loch vendace (egg) translocation in 1968 (Maitland, 2007). However, this failed - probably due to the severe acidification of the loch. Acidity is now much reduced (Marine Scotland Science pers. Comm.) and an introduction from the Derwent Water vendace population was carried out in 2011 (Lyle & Dodd, 2011). Some 70,000 eyed eggs nearing hatching were transferred to Loch Valley in March 2011 (Table 1; Fig. 2) and a survey to determine if this has been successful should be conducted within the next few years.

Powan

Loch Sloy and Carron Valley Reservoir

Between 1988 and 1990 both male and female powan were collected at spawning time (January) on known spawning grounds in Loch Lomond and eggs stripped from 22 ovulating females, fertilised with milt from mature males and incubated until hatching. Before the emerging fry had utilised the nutrition from their yolk-sac and thus begun exogenous feeding, ca 13,100 unfed fry were released to a refuge site at Carron Valley Reservoir and ca 12,200 to Loch Sloy. An additional 85 adult fish were also translocated to Loch Sloy. Multiple subsequent surveys to examine the status of these translocated populations have shown that they are well established and flourishing. The detail of these translocation efforts have been described elsewhere (see Maitland & Lyle, 2013)

Table 1. Conservation translocations of Arctic charr, vendace and powan in Scotland the source and destination sites, material transferred and establishment success, since 1985. Number of families is an indication of the number of full or half sibling groups translocated (except when marked * which indicates the number of groups comprising eggs from a single female) ([a] more detail in Maitland & Lyle, 2013).

Species	Year	Source	Destination	Life stage (N)	Number of families	Successful establishment?
Arctic charr	1986-1990[a]	Loch Doon	Talla Reservoir	Adults (131) Juveniles (31)	unknown	Yes
Arctic charr	1986-1990[a]	Loch Doon	Megget Reservoir	Alevins (18,300)	101*	Yes
Vendace	1998[a] 2005 & 2008[a]	Derwent Water	Daer reservoir	Unfed fry (12,800) Adults (25) Eggs (32,300)	6* 14*	Uncertain
Vendace	1997 & 1999[a]	Bassenthwaite Lake	Loch Skeen	Unfed fry (17,500) Eggs (47,500)	35*	Yes
Vendace	2011[a]	Derwent Water	Loch Valley	Eggs (70,000)	33*	Unknown
Powan	1988-1990[a]	Loch Lomond	Carron Valley Reservoir	Unfed fry (13,100)	22*	Yes
Powan	1988-1990[a]	Loch Lomond	Loch Sloy	Unfed fry (12,200) Adults (85)	22* Unknown	Yes
Powan	2009	Loch Sloy (Lomond origin powan)	Lochan Shira	Eggs (10,200) Eggs (39,200)	9 41	Unknown
Powan	2010	Loch Lomond	Lochan Shira	Unfed fry (51,100)	46	Unknown
Powan	2009	Loch Sloy (Lomond origin powan)	Allt na Lairige	Eggs (6840) Eggs (23,040)	9	Unknown
Powan	2010	Loch Lomond	Allt na Lairige	Unfed fry (41,800)	46 41	Unknown
Powan	2010	Loch Eck	Loch Tarsan	Unfed fry (115,300)	168 unknown	Unknown
Powan	2011	Loch Eck	Loch Tarsan	Unfed fry (9,000) Adults (150)		Unknown
Powan	2010	Loch Eck	Loch Glashan	Unfed fry (90,600)	168	Unknown
Powan	2011	Loch Eck	Loch Glashan	Unfed fry (9,000) Adults (136)		Unknown

Table 2. The search criteria use to find sites suitable for supporting a conservation refuge (Ark) site for powan from Lochs Lomond and Eck using the criteria of the IUCN (IUCN 1997) modified to include site characteristics meeting the ecological needs of a self-sustaining population for the species and for features of the site that would be likely to support long-term ecosystem and population security.

Search criteria	Evaluation	Rational
Ecosystem conservation importance	Ecosystem unmodified and/or of conservation value	Systems that have been highly modified for other reasons (such as reservoirs) are less likely to support important fish communities
Geographic location	Proximity to site of origin	
Physical site characteristics	Waterbody area and volume	Larger waterbody size will support a larger and thus more robust refuge population
	Altitude	Higher altitude – greater buffering from climate change
	Maximum and mean depth	Greater depth more deep water refuge
	Suitable spawning habitat	A reasonable proportion of the littoral zone with suitable spawning substrate
Loch Hydrology	Water level maximum, minimum and range during the spawning period	Reduced water level during the egg incubation period – greater risk to egg survival
Water chemistry	Overall nutrient loading	High nutrient loading unsuitable for powan
	pH	Low pH unsuitable for powan
Fish community	No populations of powan in a directly connected water	Risk of genetic introgression between diverged populations
	No populations of Arctic charr in a directly connected water	Risk of competition between these two species
Recreational fisheries	Active management for exploited species	Some recreational fishery management practices are likely to be unsuitable for powan
Security	Possible long-term changes to the catchment or water body that might be detrimental to an establishing powan population	

Lochs Tarsan & Glashan, Lochan Shira & Allt na Lairige

In 2007 as a result of potential additional risks to the established conservation refuge population of powan in Loch Sloy from proposals by Scottish and Southern Energy (SSE) to modify the hydro-power scheme there, plus consideration of potential risks to the Loch Eck powan population (which did not have a conservation refuge), a search began for possible suitable sites to create two more conservation refuge sites for powan from each of the Loch Lomond and Loch Eck populations. SSE offered seven hydro-electric reservoirs in the region for assessment as potential refuge sites. To determine the suitability of sites from amongst these as long term host sites for powan, existing information was collated and evaluated in a desk study against criteria drawn from international guidelines for conservation translocations (IUCN, 1998; IUCN, 2012) These criteria specify site characteristics meeting the ecological needs of a self-sustaining population for the species and for features of the site that would be likely to support long-term ecosystem and population security. The search criteria and how they were used in practice are described further here (Table 2).

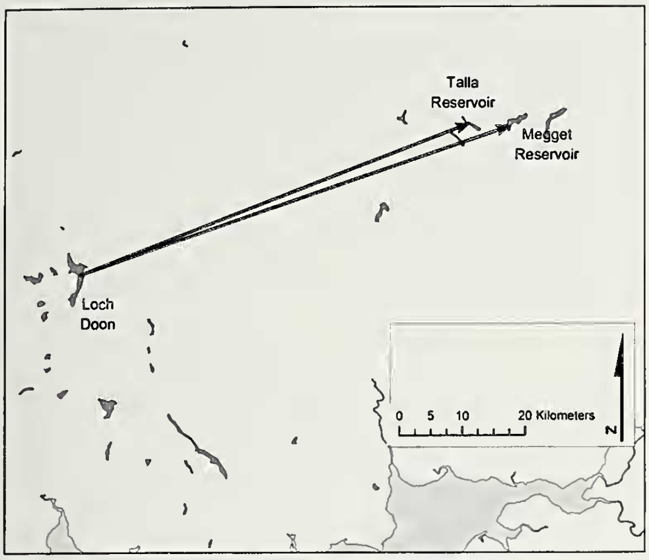


Fig. 1. A map of south-west Scotland, showing Arctic charr source population (Loch Doon) and conservation refuge sites (Talla and Megget Reservoirs).

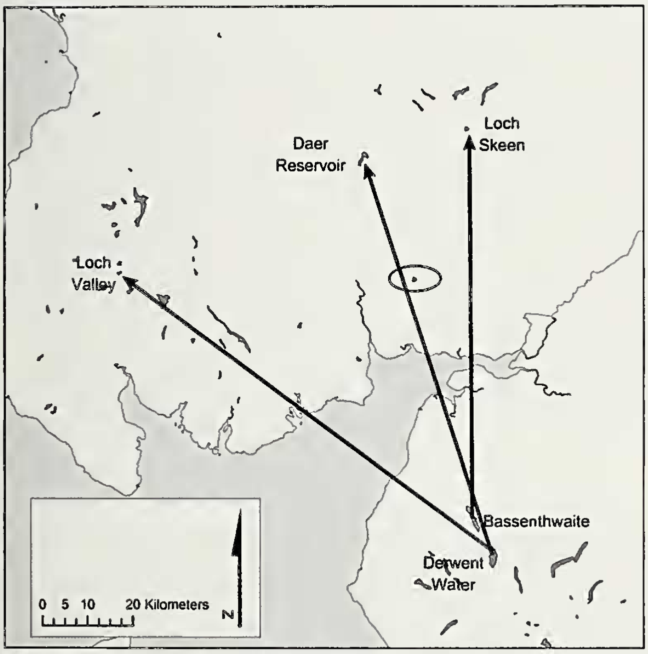


Fig. 2. A map of south-west Scotland and north-west England showing vendace source populations (Bassenthwaite Lake and Derwent Water) and conservation refuge sites (Loch Skeen, Loch Valley and Daer Reservoir). The location of the now extinct Castle and Mill Lochs vendace populations are highlighted by the ellipse.

SITE EVALUATION

Ecosystem conservation importance - IUCN Guidelines for Re-Introductions (IUCN, 1998; IUCN, 2012) indicate that any conservation translocation should not be carried out if there is the possibility of this resulting in significant damage to an ecosystem of high conservation value at the refuge site. In this case the reservoirs in question were established by impoundment, either of an existing loch, or to create a new loch where none existed previously, and were therefore less likely to have a high conservation value, although this was still assessed.

Geographic location - IUCN guidelines (IUCN, 1998; IUCN, 2012) recommend that the introduction sites should, where possible, be located as close to the donor site as possible. Thus the relative proximities of the candidate reservoirs to Lochs Lomond and Eck were considered as a criteria for assessment of possible translocation sites.

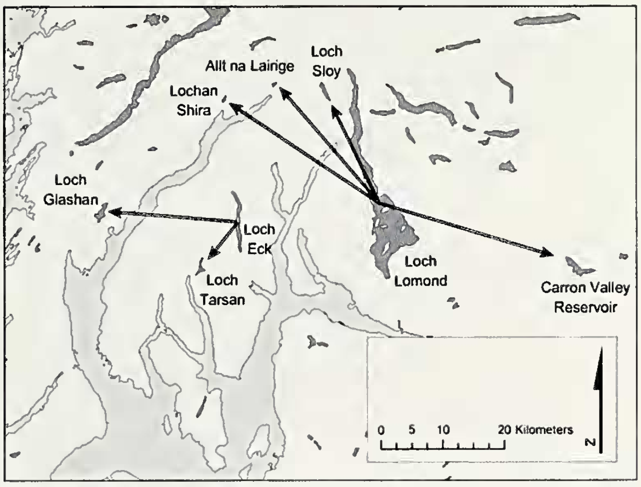


Fig. 3. A map of west-central Scotland showing powan source populations (Loch Lomond and Lock Eck) and the location of the conservation refuge sites (Carron Valley Reservoir, Loch Sloy, Lochan Shira, Allt na Lairige reservoir, Loch Tarsan and Loch Glashan).

Physical characteristics of sites – a number of specific site characteristics provide information to help evaluate the ability of the site to meet the habitat requirements of a self-sustaining powan population and its long term sustainability. The loch area and volume provide an assessment of the potential maximum powan population size that the site might support. Generally, larger sites have the potential to support a larger population size, which may be less affected by genetic drift, when compared with sites of a relatively smaller size. Powan require relatively cool water and, with the potential of some surface waters of Scottish lochs to exceed temperatures that may be lethal for powan (Maitland & Lyle, 2013), one habitat requirement is an available deep water refuge of significant size. Thus maximum depth, mean depth and the size of the deep water area of the putative refuge sites were regarded as important. Volume development (V_d) was used as a proxy for the size of the deep water refuge where $V_d = 3D_{mean}/ D_{max}$ (Hakanson, 1981). A higher value of V_d denoting a greater proportion of deep water and therefore greater suitability for powan. In the absence of empirical data, the altitude of a site provides a measure of the probable temperature range of the water; higher altitudes indicating lower summer mean temperature. Altitude was also used as an indication of the potential long term security of the site, with higher altitude buffering against the effects of future temperature rise resulting from climate change.

Hydrology - powan spawn over the littoral and sub-littoral submerged beaches with suitable substrates, (Maitland & Lyle, 2013), water level regimes during the spawning and egg incubation periods (December to April) are thus very important to breeding success. Historical maximum and minimum water levels and water drawdown levels during the spawning and incubation periods were available for all the reservoir sites. The temporal drawdown regime was of particular importance, as the potential for eggs that were spawned in shallow water and then during their incubation being exposed by a drop in water level, resulting in either freezing or desiccation, would result in high egg mortality.

Water chemistry – powan require oligo-meso trophic water conditions (Maitland & Lyle, 2013) . For some sites, long term water chemistry data were available from the Scottish Environment Protection Agency (SEPA). The status of pH, conductivity, alkalinity, nitrate and total phosphorus were of particular interest in determining whether water chemistry was likely to meet the needs of this species.

Fish community – information from literature, Fisheries Trusts, angling clubs and local contacts was collected to establish what was known of the sites's fish communities. This also included information relating to fish stocking practices and other fish introductions.

Field Evaluation – all seven sites were visited and surveyed to determine the fish community structure. Of particular importance was the potential presence of pike (*Esox Lucius* L.) perch (*Perca fluviatilis* L.) or ruffe, a large population of any of these has the potential to prevent successful establishment of a potential prey species. The presence of Arctic charr was regarded as equally undesirable, being a high conservation value species with which powan are likely to compete. The availability and extent of good quality spawning areas was also assessed. Powan require a mixture of substrates ranging from gravels and cobbles in water depths from one to seven metres and an absence of fine silts (which may inhibit oxygen diffusion across respiring, incubating eggs) (Maitland & Lyle, 2013). Substrate could be best assessed at low (usually summer) water levels or by using a bathyscope and underwater Remotely Operated Vehicle (ROV) from either a boat or the shore as appropriate.

Determining the most suitable sites - the above data for the seven reservoirs were compiled and presented in detail to an expert panel comprising 11 individuals with a broad range of expertise in related fields and discussed. This process often referred to as the 'Delphi process' is particularly useful in situations where data partially limit decision making and it is an approach which has been used in the context of conservation management previously (MacMillan & Marshall, 2006). This process resulted in the identification of four reservoirs as possible refuge sites - Alt na Lairige and Lochan Shira for Loch Lomond powan and Loch Tarsan and Loch Glashan for Loch Eck powan.

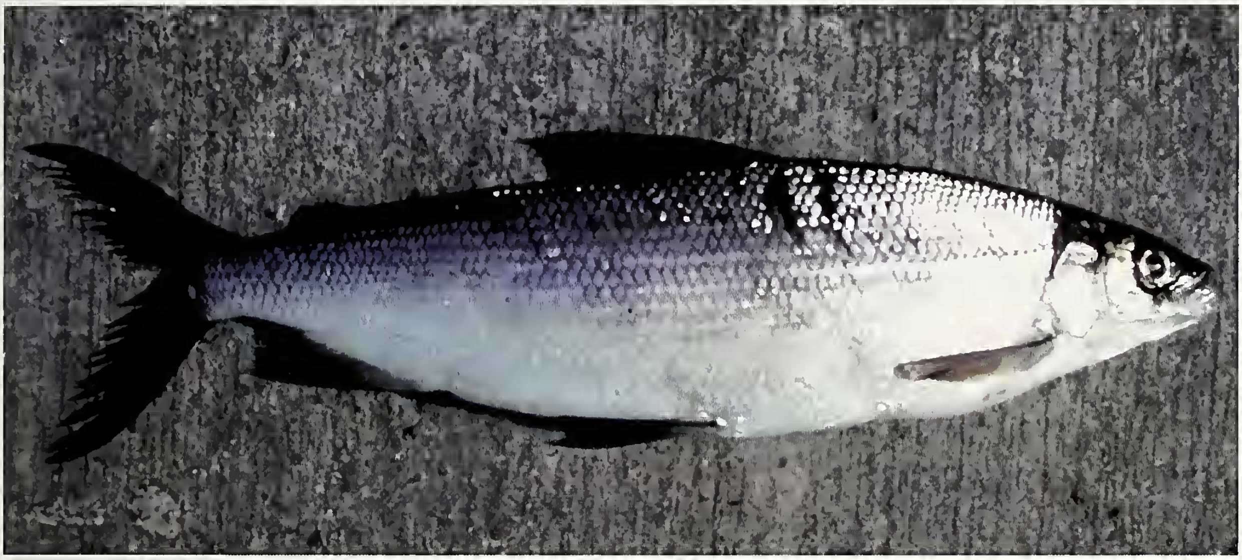
CONCLUSION

Over the last 40 years, translocation to establish new, conservation refuge populations of rare lacustrine fishes has formed an important component part of the conservation effort of three species in Scotland. Two conservation refuge populations have been successfully established for Arctic charr from one threatened population. Three translocations of vendace from two endangered (one now extinct) populations in the English Lake District have resulted in the successful establishment of at least one conservation refuge population, the other two have not yet been confirmed. Greatest effort has focussed on powan, which has seen attempts to establish conservation refuge populations for two native populations under threat. Two of these have established successfully, the successful establishment of the remaining four have not yet been tested.

ACKNOWLEDGEMENTS

The translocations described here were funded over a number of years by multiple agencies including Scottish and Southern Energy, Scottish Natural Heritage, the Environment Agency, English Nature (now Natural England). The authors also acknowledge the support of technical staff at the Scottish Centre for Ecology and the Natural Environment and the numerous volunteers that have helped with field work for these projects. We are grateful also to the owners of the refuge sites involved (Scottish Water, National Trust for Scotland and Scottish and Southern Energy) for permission to carry out the translocation.

Arctic charr (*Salvelinus alpinus*), fork length = 33 cm. Photo: Colin Adams.



Powan (*Coregonus lavaretus*), fork length = 29 cm. Photo: Colin Adams.

Vendace (*Coregonus albula*), fork length = 24.5 cm. Photo Alexander Lyle.

REFERENCES

Adams C.E., Fraser D., Wilson A.J., Alexander G., Ferguson M.M. & Skulason S. (2007). Patterns of phenotypic and genetic variability show hidden diversity in Scottish Arctic charr. *Ecology of Freshwater Fish* 16, 78–86.

Adams C.E. & Maitland P.S. (2001). Invasion And Establishment Of Freshwater Fish Populations In Scotland - The Experience Of The Past And Lessons For The Future. *Glasgow Naturalist* 23, 35–43.

Adams C.E. & Maitland P.S. (1998). The Ruffe population of Loch Lomond, Scotland: Its introduction, population expansion and interaction with native species. *Journal of Great Lakes Research* 24, 249–262.

Adams C.E. & Tippett R. (1991). Powan *Coregonus lavaretus* (L.) ova predation by newly introduced ruffe, Gymnocephalus cernuus (L.) in Loch Lomond, Scotland. Aquaculture and Fisheries Management 22, 239–246.

Albrecht G. A., Brooke C., Bennett D.H. & Garnett S.T. (2012). The Ethics of Assisted Colonization in the Age of Anthropogenic Climate Change. *Journal of Agricultural and Environmental Ethics* 26, 827–845.

Alexander G.D. & Adams C.E. (2000). The phenotypic diversity of Arctic charr , *Salvelinus alpinus*, (Salmonidae) in Scotland and Ireland. *Aqua* 4, 77-88.

Chauvenet A.L.M., Ewen J.G., Armstrong D.P., Blackburn T.M. & Pettorelli N. (2013). Maximizing the success of assisted colonizations. *Animal Conservation* 16, 161–169.

Coleman R. A., Weeks A. R. & Hoffmann A.A. (2013). Balancing genetic uniqueness and genetic variation in determining conservation and translocation strategies: a comprehensive case study of threatened dwarf galaxias, *Galaxiella pusilla* (Mack) (Pisces: Galaxiidae). *Molecular Ecology* 22, 1820–35.

Etheridge E.C., Bean C.W., Maitland P.S., Ballantyne S. & Adams C.E. (2012) Discontinuous infraspecifi c variation in ecological and morphological traits has consequences for conservation of powan (*Coregonus lavaretus*) in Scotland. *Advances in Limnology* 63, 505–517.

Hakanson, L. (1981). *A Manual of Lake Morphometry*. Springer-Verlag, Heidelberg.

IUCN (1998). *Guidelines for Re-Introductions*. IUCN, Gland, Switzerland.

IUCN (2012). *IUCN Guidelines for Reintroductions and Other Conservation Translocations*. IUCN, Gland, Switzerland.

Linklater W.L., Adcock K., du Preez, P., Swaisgood R.R., Law P.R., Knight M.H., Gedir, J.V. & Kerley, G.I.H., (2011). Guidelines for large herbivore translocation simplified: black rhinoceros case study. *Journal of Applied Ecology* 48, 493–502.

MacMillan D.C. & Marshall K. (2006). The Delphi process? an expert-based approach to ecological modelling in data-poor environments. *Animal Conservation* 9, 11–19.

Maitland P.S. & Lyle A.A. (2013). Ex situ and in situ approaches, including assisted reproduction, for the conservation of native species of charr (Salmonidae) and whitefish (Coregonidae) in Scotland. *International Zoo Yearbook* 47, 129–139.

Maitland P.S. (1966). Present status of known populations of the vendace *Coregonus vandesius* in Great Britain. *Nature* 210, 216–217.

Maitland P.S. (2007). *Scotland's Freshwater Fish; Ecology Conservation and Folklore*. Trafford, Victoria, BC.

Maitland P.S., East K. & Morris K.H. (1983). Ruffe *Gymnocephalus cernua*, new to Scotland in Loch Lomond. *Scottish Naturalist* 1983, 7–9.

Maitland, P.S., Lyle, A.A., Ribbens, J., Graham, J. and Armstrong, R. 2009. *Translocation of sparling: 2009*. Scottish Natural Heritage, Inverness.

Müller H. & Eriksson O. (2013). A pragmatic and utilitarian view of species translocation as a tool in conservation biology. *Biodiversity and Conservation* 22, 1837–1841.

Thrimawithana a. H., Ortiz-Catedral L., Rodrigo a. & Hauber M.E. (2013). Reduced total genetic diversity following translocations? A metapopulation approach. *Conservation Genetics* 14, 1043–1055.

Wilson A. J., Gíslason D., Skúlason S., Snorrason S.S., Adams C.E., Alexander G., Danzmann, R.G., Ferguson, M.M. (2004). Population genetic structure of Arctic charr, *Salvelinus alpinus* from northwest Europe on large and small spatial scales. *Molecular Ecology* 13, 1129–42.

Winfield I.J., Adams C.E., Bean C.W., Durie N.C., Fletcher J.M., Gowans A.R., Harrod, C., James, J.B., Lyle, A.A., Maitland, P.S., Thompson, C. & Verspoor, E.. (2012). Conservation of the vendace (*Coregonus albula*), the U .K.' s rarest freshwater fish. *Advances in Limnology* 63, 547–559.

Zeisset I. & Beebee T.J.C. (2013). Donor population size rather than local adaptation can be a key determinant of amphibian translocation success. *Animal Conservation* 16, 359–366.